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balansa v morskikh usloviyakh."

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ABSTRACT

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The article presents the results of investigating balance meters with polyethylene coatings of various forms under different meteorological conditions. Some errors are examined which occur when the radiation balance is measured at sea.

Recommendations are presented for carrying out the most accurate measurements of radiation balance at sea. *Grish*

The sea radiation balance measurement from large ships presents some difficulties.

In the first place, it is necessary to eliminate the effect of the ship's hull on the reading of the balance meter. For this purpose, the balance meter must be attached to the end of a boom extended from the ship's bow. When the boom with the actinometric devices is positioned in this manner, the effect of the shadow produced by the ship and the effect of the additional illuminations on the reading of the devices will be at a minimum. Furthermore, when the boom is extended from the ship's bow, the actinometric devices are situated over the water surface which is not distorted by the movement of the ship.

Numerical calculations show that the error in measuring the radiation balance caused by the effect of the ship does not exceed 5 percent in the case when the length of the boom carrying the actinometric devices is not less than the height of the ship's bow (ref. 7).

In the second place, in addition to the usual wind flow past the balance meter, due to keel rolling, there is a vertical air movement around the balance meter produced by the up and down movement of the meter with respect to the air. As a result of this, the flow past the upper and lower surfaces of the balance meter is not equal, which leads to additional errors.

Furthermore, during operation at sea the sensing surfaces of the balance meter are sometimes splashed by sea water and the salt precipitates on them. A balance meter wetted by even a few droplets of water does not give a correct reading.

Due to the vertical air flow around the balance meter and the splashing of water over it, the measurements made with the unprotected radiation balance meter become very unreliable under sea conditions. Therefore, in recent marine actinometric observations, it has become a practice to cover the balance meters with a polyethylene film which eliminates the effects of wind and droplets of sea water on the sensing surfaces of the balance meter.

In this connection, a need has arisen for a comprehensive investigation of balance meters with polyethylene coatings.

This article presents the results of several investigations which we conducted in the spring-summer of 1962 at the Karadagh Actinometric Observatory.

Figure 1 shows the transmission curve of the polyethylene film with a thickness of $60\ \mu$ obtained from the measurements of L. B. Krasil'shchikov in the interval from 1-15 μ . As the figure indicates, the polyethylene produces a strong absorption of radiation in the region of wavelengths 3.5, 7.0 and 14 μ .

However, we should note that the width of the absorption bands is not very large. In all of the remaining spectral intervals a polyethylene film with a thickness of $60\ \mu$ transmits approximately 90 percent of the radiation.

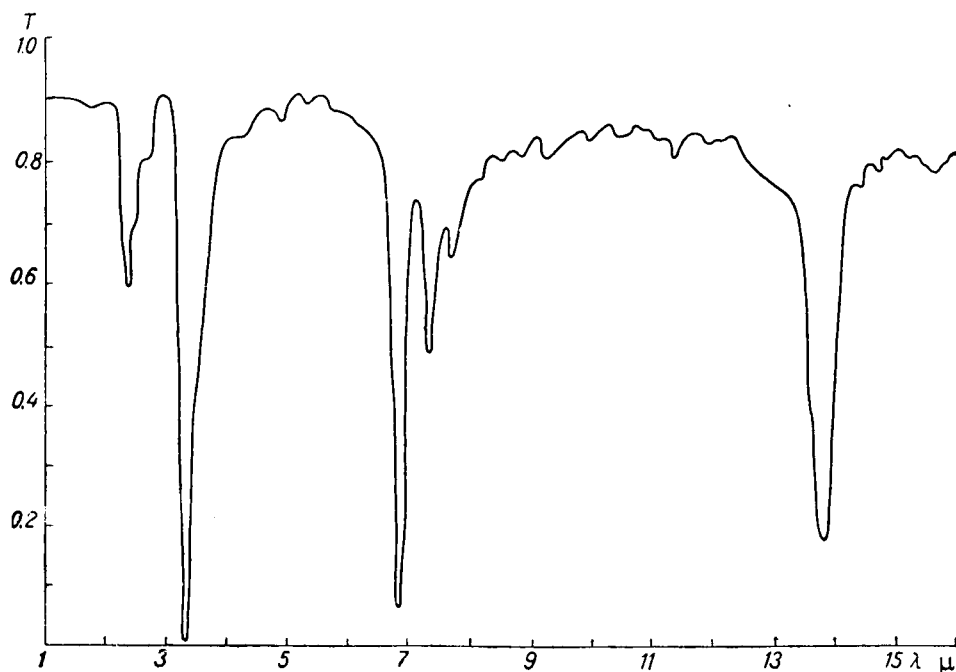


Figure 1. Spectral transparency of a polyethylene film.

The data measured by L. B. Krasil'shchikov were compared with the transmission measurements of American polyethylene with a thickness of 0.1 mm (ref. 9). As a result of this comparison good agreement was obtained for the transmission curves of these two polyethylenes. In 1961-1962, we made a comparison between

the readings of a conventional balance meter I with the readings of balance meters covered with various forms of polyethylene coatings. Balance meter II was covered with a flat polyethylene film with a gap between the sensing surface of the balance meter and the film equal to 2 mm. The film was stretched by rings from both sides of the balance meter. The rings with the polyethylene film were attached to the balance meter by special lamellar clamps. Balance meter III was covered with a film on a hemispherical wire frame, while balance meter IV was covered with a corrugated film prefabricated from polyethylene film by a special forming press. The convexities and the concavities were placed as concentric circles from the center to the outer ring; the depth of the concavities was approximately 4 mm.

The four balance meters were attached to one stand at a height of 1.5 m above the ground. Under the devices, there was an area of level bare soil. The entire series of observations on the four balance meters took approximately 5 minutes. The wind direction and velocity were measured by the Tret'yakov anemometer. The results of the observations were processed using the methodology described in reference 8. Approximately 600 series of observations were obtained during the day and night for various altitudes of the Sun and various meteorological conditions. This made it possible to clarify the variation in the readings of the balance meters with various polyethylene coatings as a function of solar altitude above the horizon for clear and overcast conditions.

Figure 2 shows the results obtained in measuring the radiation balance for various altitudes of the Sun during a clear sky and a sky with few clouds. The measurements were obtained by a conventional balance meter I and with a balance meter II covered with a flat polyethylene filter.

Figure 3 shows the values of the balance measured by means of balance meters I and II for various h_{\odot} on separate days. (The most typical cases are selected.) As can be seen from the drawing, in some cases the values of the balance measured by balance meters I and II practically coincide. However, in a series of cases for solar altitudes which were less than $30-40^{\circ}$, the balance magnitudes measured by balance meter II is somewhat smaller (≈ 10 percent) than the values obtained with balance meter I, which may be explained by the increase in the reflected radiation from the polyethylene film when the angles of incidence of the radiation were large. For $h_{\odot} > 40^{\circ}$ the reverse picture is observed: balance magnitudes measured by balance meter II are somewhat greater than balance magnitudes measured with an open balance meter.

For comparison purposes figure 4 shows the balance curves obtained by all four balance meters. Balance magnitudes obtained by a meter with a flat filter II at high solar altitudes greater than 40° practically coincide with magnitudes measured with the unprotected meter. For $h_{\odot} < 40^{\circ}$, balance magnitudes obtained with meter II are somewhat less than those obtained with meter I.

The balance meter with a hemispherical cover III for $h_{\odot} < 40^{\circ}$ gives a value which is higher compared with that given by the unprotected balance meter

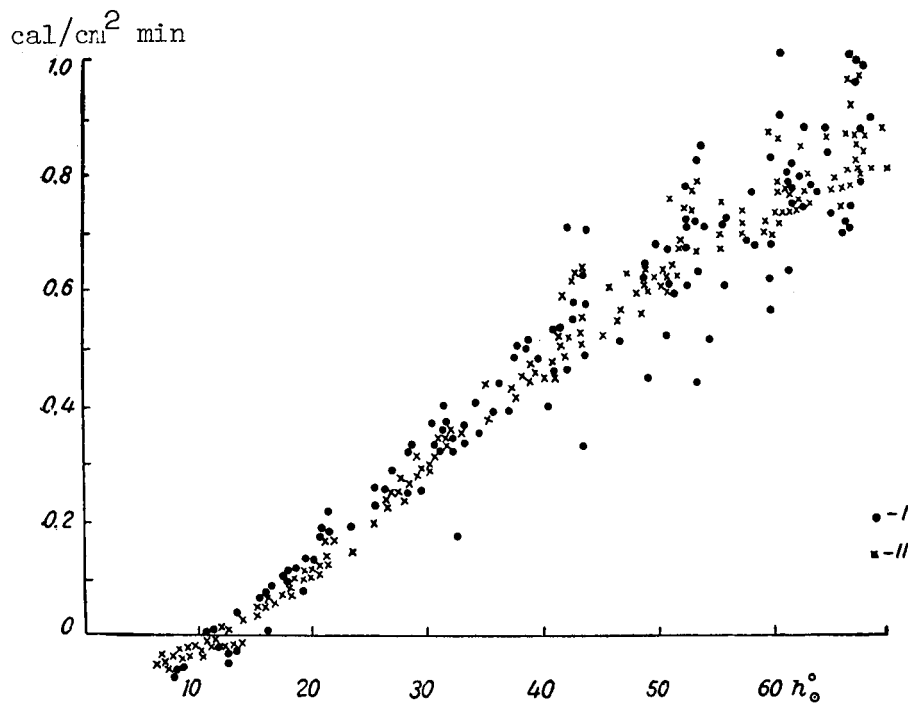


Figure 2. Values of the radiation balance obtained with a conventional balance meter (I) and a balance meter (II) covered with a flat polyethylene filter.

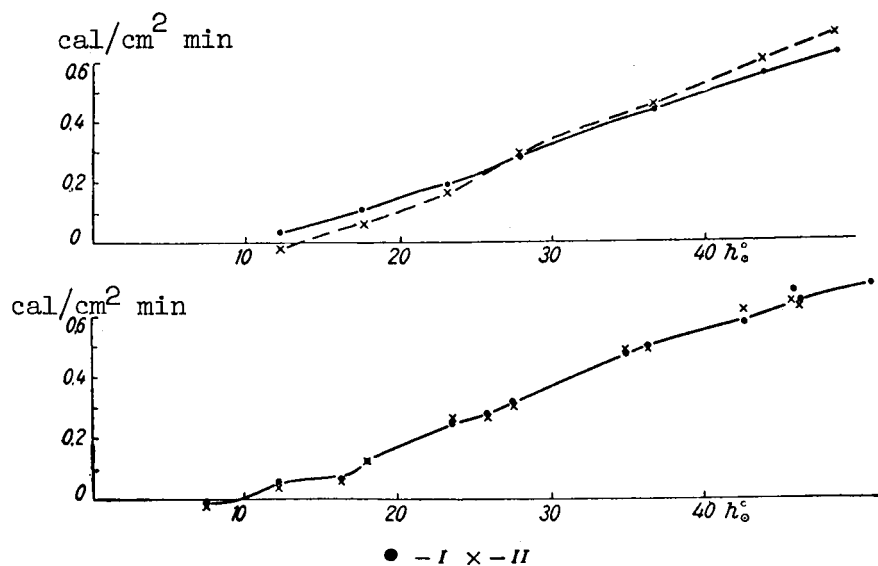


Figure 3. Radiation balance magnitudes measured by balance meters I and II on 14 September (a) and 19 September (b), 1961.

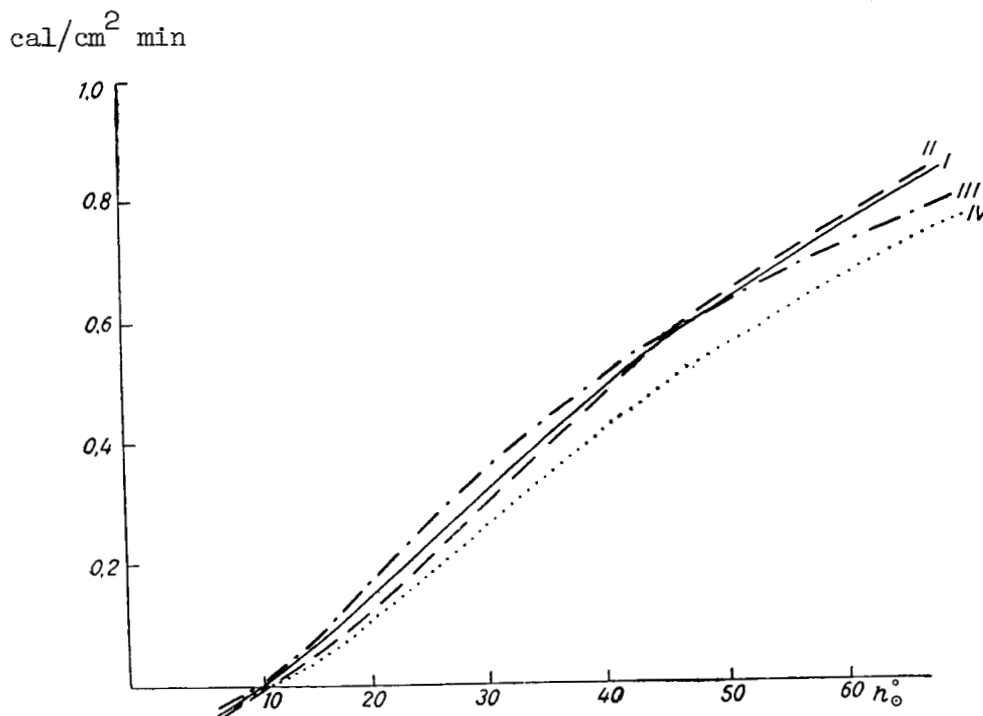


Figure 4. Results of measuring the balance by the four balance meters (I-IV).

I while for $h_{\odot} > 40^{\circ}$ it is lower. The reason for this is clear if we consider the geometry of the reflected incident radiation from the spherical polyethylene cap.

On figure 4, curve IV shows that balance magnitudes measured with the balance meter covered with a perforated film, for all altitudes of the Sun, are noticeably lower compared with the values measured with the unprotected meter. This is due to the increase in the scattering surface caused by the corrugation of the film.

Table 1 gives the data observed for the radiation balance using meters I-IV with an overcast sky. We can see from the table that radiation balance magnitudes obtained with meters I-III differ very little from each other. This is explained by the nature of the angular distribution of the scattered radiation when the sky is overcast. Slightly lower values are given by balance meter IV, which as we have pointed out is due to the increase in the scattering area.

As an example, figure 5 shows the nocturnal variation in the radiation balance taken with the unprotected meter I and with meter II covered with a flat filter. The abscissa gives the average solar time τ_m while the ordinate shows the balance in $\text{cal}/\text{cm}^2 \text{ min}$. As we can see from the drawing, balance magnitudes measured by balance meters I and II are rather close. However, in some cases the negative values of the balance measured by the unprotected meter are somewhat greater than the values measured by the meter with the polyethylene filter.

TABLE I. VALUES OF THE RADIATION BALANCE FOR THE CASE OF AN OVERCAST SKY OBTAINED BY BALANCE METERS I-IV.

Date	Time		h°_{\odot}	Form of cloudiness	I	II	III	IV
	hr	min						
20 VI	7	32	32,3	Sc	0,26	0,25	0,23	0,27
21 VI	7	31	32,1	As, Sc	0,06	0,08	0,07	0,09
21 VI	9	31	53,0	As, Sc	0,23	0,25	0,27	0,25
21 VI	10	31	61,9	As, Sc	0,19	0,19	0,17	0,18
22 VI	6	30	21,4	Ac	0,09	0,08	0,08	0,09
22 VI	7	30	31,8	Ac	0,14	0,14	0,14	0,14
23 VI	11	30	67,5	Cu	0,19	0,18	0,19	0,24
24 VI	6	30	21,4	As, Cl	0,02	0,02	0,02	0,02
24 VI	7	30	31,8	As, Cc	0,07	0,07	0,07	0,08
24 VI	9	30	52,6	As, Cc	0,22	0,19	0,17	0,18
24 VI	11	30	67,5	Ac	0,44	0,42	0,38	0,43
28 VI	10	30	61,4	Ac, Cl	0,14	0,14	0,13	0,16
29 VI	10	29	61,4	Cb, Cu, Ac	0,11	0,11	0,11	0,13
1 VII	7	28	31,1	Ac, Sc	0,18	0,18	0,17	0,19
1 VII	8	28	42,1	Sc, Ac	0,13	0,13	0,10	0,11
6 VII	10	28	60,8	Sc, Cb	0,27	0,24	0,24	0,26
19 VII	6	26	19,4	Sc, As, Cb	0,01	0,02	0,01	0,02
19 VII	8	26	40,3	Sc	0,10	0,10	0,08	0,10
20 VII	7	26	29,6	Sc, Ac	0,15	0,15	0,13	0,16

Note: Commas in these tables represent decimal points.

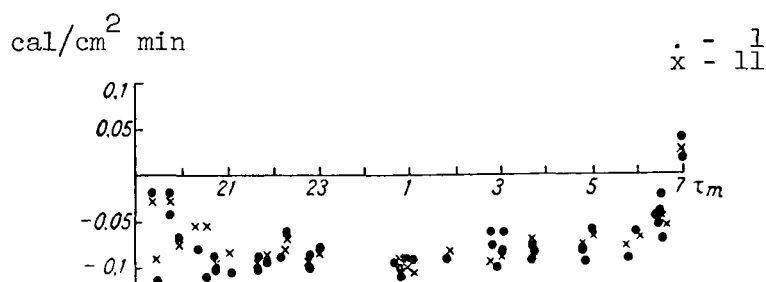


Figure 5. Nocturnal variation in the balance obtained with balance meters I-II.

Comparison of the readings of the unprotected balance meter with the readings of balance meters covered with polyethylene filters, indicates that the most suitable balance meter is the one with the flat polyethylene cover because it is simpler to fabricate and has a greater mechanical strength compared with the hemispherical unit.

When radiation balance measurements are made by the meter with the polyethylene filter, it is necessary to see whether the thermal state of the device is disrupted by the presence of the film and the layer of air between the film and the sensing surface. The clarification of this question is particularly significant because on the ship the balance meter is installed on a long boom so that the observer is unable to cover the meter after each observation. As a result of this, the balance meter is subjected to prolonged heating by solar rays.

To clarify this possible "hothouse effect" we made the following investigations. For a period of 1 hour, balance meter II with its first side upwards was held in sunlight after which it was used to measure balance B_1 . After this,

the meter was turned with its second side upwards and was used to measure balance B_2 immediately. Measurements of this type were made for a period of 1-1/2

months for different solar altitudes. As a result of these investigations, it was found that the limits of accuracy in measuring the quantities B_1 and B_2

coincided, which shows that neither the polyethylene film nor the layer of air have any practical effect on the results of measuring the balance.

In using the meter with a flat polyethylene filter, the question naturally arises concerning the angular correction of such a meter because part of the incident radiation will undergo mirror reflection from the film.

To determine the angular correction in the presence of the Sun, balance meter II was fixed on a rotating device. The lower sensing surface of the meter was covered with a screen which was rotated with the meter. Since the temperature of the lower screen did not change in the course of the measurements, the readings of the balance meter were determined in practice only by the cosine of the angle of incidence of the solar radiation. These measurements were made by us under conditions of a cloudless sky and complete calm. The results of these investigations are shown in figure 6.

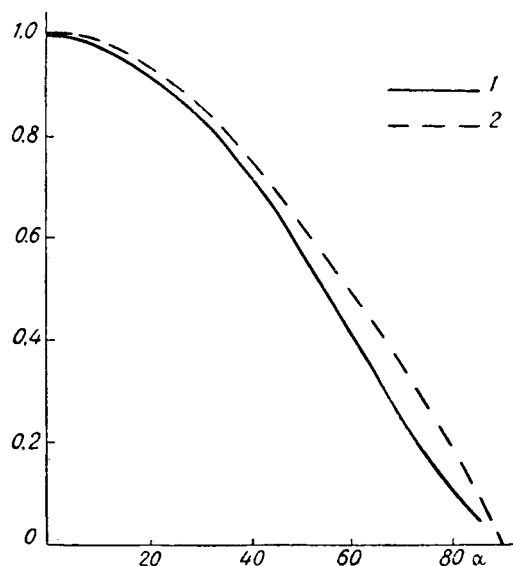


Figure 6. Variation in the sensitivity of the balance meter with a plain polyethylene film as function of the angle of incidence of the radiation $f(\alpha)$. 1 - $f(\alpha)$, 2 - $\cos \alpha$.

On the basis of the data presented in figure 6 we obtained the magnitudes of the correction factors F_h for the balance meter for different altitudes of the Sun above the horizon (Table 2).

Table 2 indicates that if we do not take into account the variation in the sensitivity of the meter as a function of the angle of incidence of the radiation, substantial measurement errors will result when $h_{\odot} < 50^{\circ}$. It is also

necessary to point out that this variation in the sensitivity of the balance meter as a function of the angle of incidence cannot be attributed only to the effect of the polyethylene film because the unprotected balance meter also has a noticeable variation in its sensitivity as a function of the radiation's angle of incidence. This is explained by the fact that the sensing surfaces of the balance meter reflect the incident radiation in a nonorthotropic manner (ref. 6).

TABLE 2

h_{\odot}°	10	30	50	70	80	90
F_h	1.72	1.28	1.06	1.05	1.01	1.0

We have also computed the correction factors for the readings obtained by the balance meter with the polyethylene filter for the case when the radiation balance is measured in the day with an overcast sky and when the balance is measured at night.

Calculations were made by taking into account the true angular distribution of scattered radiation and of the effective radiation over the sky (refs. 4 and 2). It was found that when we measure the balance in the day or at night under conditions of an overcast sky, the readings of the meter must be corrected by a factor: $f_1 = 1.10$. When measuring the radiation balance in the case of a

cloudless sky at night, it is necessary to introduce a correction factor $f_2 = 1.08$ to the readings of the balance meter. However, we should point out

that this substantial correction factor is not due only to the presence of the polyethylene film. Similar calculations made by us for a balance meter which was not protected by a polyethylene filter, have shown that in this case we must also have correction factors of the following values: $f_1 = 1.05$ and $f_2 = 1.04$.

It is interesting to note how the sensitivity of the balance meter varies when it is covered with a polyethylene film. Special investigations conducted by the authors aboard the ships "Yu. M. Shokal'skiy" and "A. I. Voyeykov," and also at the Karadagh Actinometric Observatory have shown that on the average the conversion factors of the balance meter increase by 5 percent when their sensitive surfaces are covered with polyethylene.

In view of the fact that the polyethylene film undergoes aging, it is necessary to consider the effect of this aging under natural conditions on the conversion factor of the balance meter.

At the present time, we have data on the variation of transfer factors of balance meters with positive coatings over a period of three months.

TABLE 3. DATA ON THE VARIATION IN THE CONVERSION FACTORS OF BALANCE METERS

No. of balance meter	Conversion factors 1 June 1961	Conversion factors 2 September 1961	Variation in the conversion factors, %
I	0.0190	0.0190	0
II	0.0212	0.0229	8
III	0.0196	0.0224	14
IV	0.0172	0.0192	11

Table 3 shows the conversion factors of an unprotected balance meter I and of three balance meters with polyethylene filters, II, III and IV, obtained when checking out the balance meters on June 1 and September 2, 1961. As the table shows, after a three-month summer exploitation (it is important to note that at Karadagh the balance meters were subjected to daily intense illumination by solar radiation) the conversion factors of meters with polyethylene coatings increased on the average by 11 percent while the conversion factor of the unprotected balance meter remained unchanged. The smallest variation (by 8 percent) of the conversion factor took place in the meter with the flat coating.

It follows that balance meters with polyethylene filters must be checked not less than once a month. It is also necessary to point out that polyethylene coatings require daily inspection. If ocean salt is detected on the surface of the film it should be wiped with a soft cloth wetted in distilled water.

When the radiation balance is measured at sea, a periodic sweating of the polyethylene film may occur. When moisture is detected on the inner surface of the film the polyethylene film should be opened and the balance meter and film dried out.

In considering the problem of measuring the radiation balance at sea from various ships it is necessary to consider the followings conditions. When we measure the radiation balance on land we shade the balance meter from the direct solar rays and add the direct radiation obtained from the actinometric measurements to the readings of the balance meter. Under sea conditions, it becomes impossible to shade the balance meter from the direct solar radiation since it is installed at the end of a long boom. Because observations with an unshaded

balance meter will obviously be less accurate, we carried out special investigations to determine what error is obtained if observations are made with an unshaded balance meter.

The balance was measured simultaneously with two meters of which one was shaded from the direct rays of the Sun while the second one was not. Measurements were made for various altitudes of the Sun above the horizon. By comparing the readings of these balance meters it became clear that for high solar altitudes (30° - 60°) the measurement error which occurs when the balance meter is not shaded is between 0 to 5 percent. For solar altitudes below 30° , this error increases rapidly as the altitude of the Sun decreases over the horizon and when $h_{\odot} = 10^{\circ}$ it is already 30 percent (fig. 7). The same figure shows the result

of similar measurements for a balance meter covered with the polyethylene filter. For $h_{\odot} = 30^{\circ}$ - 50° the measurement error for an unshaded balance meter is between

10-20 percent, for $h_{\odot} = 20^{\circ}$ the error is approximately 50 percent, while for $h_{\odot} = 10^{\circ}$ it is 60-70 percent.

Thus, we see that for low solar altitudes the measurement of the radiation balance of the sea from a ship becomes unreliable. The reason for such large errors in the balance measurement during low solar altitudes is the variation in the sensitivity of the meter as a function of the angle of incidence of the radiation which we have described above and also the reflection of radiation from the polyethylene film. In this connection when measuring the sea radiation balance it is desirable to introduce an angular correction to the conversion factor of the balance meter.

We shall consider in detail a series of errors which take place when the radiation balance is measured at sea.

(1) An error in measuring the longwave radiation and the radiation balance due to the shading of part of the water surface by the ship. Figure 8 shows a ship with a boom (l is the length of the boom, a is the length of the bow of the ship, $2d$ is the width of the ship, h is the height of the ship above the water; $L = l + a$).

Let us determine the angle at which the ship is visible from the center of the balance meter, $\omega L^2 = L \cdot 2d = S$ where S is the area of the ship's surface produced by a vertical plane along the line AB.

For simplicity, we shall assume that triangle ABC is isosceles, then

$$a = \sqrt{3} d, \quad \omega = \frac{2dh}{L^2} = \frac{2dh}{(l + \sqrt{3} d)^2}.$$

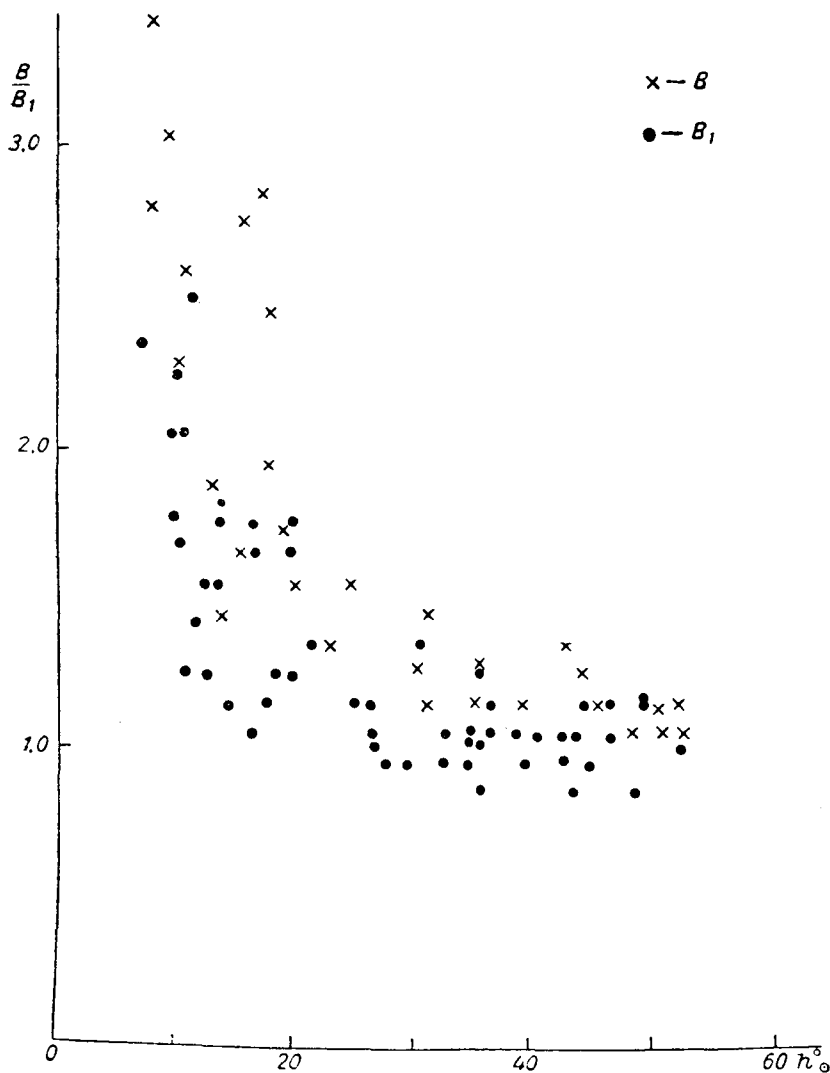


Figure 7. Ratio of radiation balance magnitudes measured by a balance meter shaded from the direct solar radiation in conjunction with an actinometer (B) and measured with an unshaded balance meter (B_1).

The natural longwave radiation of the ship per unit solid angle will be written in the following form:

$$F_1(\omega) = \frac{\delta_s \sigma T_s^4 \omega}{2\pi} = \frac{\delta_s \sigma T_s^4 dh}{\pi (l+a)^2},$$

where δ_{ship} is the relative emissive power of the ship. According to the data of reference 11 $\delta_{\text{ship}} = 0.9$.

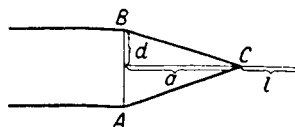


Figure 8.

If the ship were absent, the meter would obtain the following amount of longwave radiation, emitted by the water surface,

$$\delta_w \sigma T_w^4$$

The longwave radiation of the water surface which is reflected by the ship may be written in the form:

$$\delta_w \sigma T_w^4 (1 - \delta_s).$$

The quantities F_{longwave} were computed by us for the following ship parameters, $d = 9$ m, $a = 20$ m, $l = 8$ m, $\delta_s = 0.90$, $F_1 = 0.0292$, $\delta_s = \sigma T^4$.

Table 4 shows the values of F_1 for various temperatures of the ship.

TABLE 4.

T_s	F_1 cal/cm ² min	T_s	F_1 cal/cm ² min
5	0.011	25	0.017
10	0.014	30	0.018
15	0.015	35	0.019
20	0.016	40	0.021

The values of the emissive power of water into a hemisphere were computed by us for the water temperature range of 0-30°, and we shall discuss this in more detail below. Within the given limits of temperature variation the emissive power of water varies little and for a smooth water surface constitutes on the average 89 percent, and 91 percent when the water is wavy.

Table 5 presents the values of the longwave radiation emitted by the water surface for various water temperatures.

The values of the long range radiation reflected by the ship computed for different water temperatures are shown in Table 6.

Table 7 presents the errors (percent) due to the shading of the longwave radiation by the ship. These were obtained in the following manner,

TABLE 5.

T_W	σT_W^4	$\delta \sigma T_W^4 \frac{\omega}{2\pi}$
0	0,40	0,012
5	0,44	0,013
10	0,47	0,014
15	0,50	0,015
20	0,54	0,016
25	0,58	0,017
30	0,62	0,018
35	0,66	0,020

TABLE 6.

T_W	$\delta \sigma T_W^4 (1 - \delta_S)$	$\delta \sigma T_W^4 (1 - \delta_S) \frac{\omega}{2\pi}$
0	0,040	0,001
5	0,044	0,001
10	0,047	0,001
15	0,050	0,001
20	0,054	0,002
25	0,058	0,002
30	0,062	0,002
35	0,066	0,002

$$\delta \sigma T_W^4 - \delta \sigma T_W^4 \left(1 - \frac{\omega}{2\pi}\right) - F(\omega) + \delta \sigma T_W^4 (1 - \delta_S) \frac{\omega}{2\pi} =$$

$$= \delta \sigma T_W^4 \frac{\omega}{2\pi} - F_1(\omega) + \delta \sigma T_W^4 (1 - \delta_S) \frac{\omega}{2\pi}.$$

The errors were determined for various possible water temperatures and ship temperatures.

As can be seen from the table, the errors incurred in measuring the long range radiation due to the shading by the ship of part of the longwave radiation do not exceed 0.5 percent under actual operating conditions. Table 8 presents the values of the errors incurred in measuring the radiation balance due to the shading by the ship of the longwave radiation (percent). The errors are computed for various water temperatures and ship temperatures.

TABLE 7.

T_W	T_S							
	5	10	15	20	25	30	35	40
0	0,5	0,2	0,5					
5		0,0	0,2	0,4				
10			0,0	0,2	0,4			
15				0,0	0,2	0,4		
20					0,2	0,0	0,2	
25						0,2	0,0	0,3
30							0,2	0,2

TABLE 8.

T_W	T_S							
	5	10	15	20	25	30	35	40
0	0,5	0,2	0,5					
5		0,0	0,2	0,5				
10			0,0	0,2	0,5			
15				0,0	0,2	0,5		
20					0,2	0,0	0,2	
25						0,2	0,0	0,5
30							0,2	0,2

As the table shows, the magnitude of the error in measuring the radiation balance due to the shading by the ship of the longwave radiation does not exceed 0.5 percent.

(2) The error incurred in measuring the radiation balance due to the deviation of the balance meter from a horizontal position. As we know this deviation

may lead to substantial errors. In cases when the balance meter is fixed on a Cardan's suspension, these errors, naturally, cannot be substantial, however, a check of several Cardan's suspensions made by us has shown that these suspensions provide a horizontal position with an accuracy of 1 to 4° when the ship rolls. In this connection we investigated the errors in measuring the balance when the meter deviates from the horizontal position.

As a result of these investigations, we found that in those cases when the rolling of the balance meter takes place around an axis whose direction coincides with the azimuth of the Sun, the deviation of the balance meter from the horizontal position leads to very small errors in the measured values of the balance not exceeding 3 percent. In cases when the rolling of the balance meter takes place around an axis perpendicular to the azimuth of the Sun, then even a small inclination of the balance meter may lead to noticeable errors when we determine the balance.

Thus, during the deviation of the sensing surface of the meter from a horizontal position α by 1° the magnitude of $\Delta B/B$ constitutes 20 percent, while for $\alpha = 3^\circ$ the magnitude at $\Delta B/B$ constitutes 40 percent.

In this connection, when we measure the balance at sea, it is necessary to check continuously on the strictly horizontal position of the balance meter. When the ship rolls, it is necessary to turn until the rolling has a minimum value.

(3) The error in measuring the radiation balance due to water falling on the sensing surfaces of the balance meter. Under conditions at sea it is possible to get water on the sensing surfaces of the balance meter (splashing of sea water, precipitation, dew). Sweating of the polyethylene filter is also possible. We carried out investigations to determine what effect this can have on readings by using a balance meter covered with a polyethylene filter splashed with sea water.

The measurements were made at different times of the day with different degrees of cloudiness. The splashing of the balance meter was done artificially. First, the upper surface of the balance meter covered with the polyethylene filter was splashed and the balance was measured. Then, the lower surface of the balance meter was splashed (Table 9) or the reverse procedure was used whereby the lower surface was splashed first and then the upper surface (Table 10), after which the balance was measured again. Following this the polyethylene filter of the meter was wiped and the balance was again measured.

From Tables 9 and 10 we can see that when water droplets fall on the polyethylene the reading of the balance meter changes radically. Thus, when the upper surface of the balance meter is splashed the balance decreases sharply. When the altitude of the Sun is 20-50° the balance decreases by 40-50 percent on the average. When the altitudes of the Sun are less than 20°, there is a more substantial variation in the balance magnitudes in some cases exceeding 100 percent. When droplets of water fall on the lower surface of the balance meter, which is covered with the polyethylene filter, we get a substantial

TABLE 9.

Date	Time		h_{\odot}	Cloudi- ness	B	B_{wet} from top	B_{wet} from both sides	B_{wiped}
	hr	min						
5 IX	15	15	33,0	0/0	25,2	16,6	29,5	25,0
	15	45	28,3	0/0	17,7	6,0	19,3	17,8
	16	37	19,6	0/0	3,7	-5,4	3,8	3,5
	17	33	9,5	0/0	-6,6	-9,3	-3,4	-6,9
	18	06	3,7	0/0	-9,3	-8,1	-5,4	-9,2
6 IX	7	13	17,7	0/0	8,3	1,6	9,4	8,0
	8	04	26,3	0/0	20,6	8,1	22,5	22,1
	9	55	42,9	0/0	44,6	32,4	51,0	45,3
	11	36	51,1	0/0	48,2	45,1	61,0	50,4
7 IX	12	20	51,0	0/0	51,9	48,1	62,8	52,1
	15	54	26,5	10/0	15,4	9,3	19,6	13,9
8 IX	11	47	50,7	0/0	54,3	49,6	64,1	55,1
4 X	15	26	22,9	9/2	13,9	9,3	14,8	14,2
	15	48	19,3	9/2	1,8	-0,4	3,7	1,8
	19	43	<0	10/4	-2,5	-3,7	-1,7	-2,5
5 X	21	52	<0	10/4	-2,5	-3,8	-1,7	-2,6
	9	40	31,9	2/0	18,7	13,5	18,8	19,1
	19	42	<0	0/0	-1,1	-2,6	-1,0	-1,1

TABLE 10

Date	Time		h_{\odot}	Cloudi- ness	B	B_{wet} from bottom	B_{wet} from both sides	B_{wiped}
	hr	min						
4 X	13	46	3,55	9/2	11,8	18,4	13,8	11,9
	15	29	22,5	10/4	13,4	18,1	13,4	11,8
	15	36	21,4	10/4	6,0	10,3	6,9	5,8
	15	48	19,3	10/4	1,8	5,5	4,2	2,0
	19	49	<0	10/4	-2,4	-0,7	-1,7	-2,4
	21	54	<0	10/2	-2,6	-0,7	-1,6	-2,6
5 X	19	42	<0	0/0	-1,1	0,3	-0,6	-1,0

increase in the balance readings (on the average by 50 percent). When both surfaces of the meter are splashed with droplets of sea water the magnitude of the balance increases by 20-30 percent on the average, but in individual cases (usually for small values of h_{\odot}) the variation in the balance magnitude reaches 90-100 percent.

Such measurements of the balance when the meter was splashed with sea water were carried out during the day with the balance meter shaded from the direct solar rays, and also at night (see $h_{\odot} < 0$ in Table 10). When the

meter is shaded from the Sun the value of the balance varies approximately within the same limits as when the Sun is not shaded. It was found that at night the splashing of one of the sides of the balance meter leads to a variation in the magnitude of the balance by 80 percent on the average, while the splashing of both sides leads to an average increase of 30 percent in the

balance. Everything stated above shows that when there is severe rolling and when there is a constant splashing of the sensing surfaces of the balance meter by sea water, the balance measurement should be stopped. When there is a single accidental splashing of the sensing surfaces of the balance meter, which are covered with a polyethylene filter, or when rain drops (or dew) have fallen, the sensing surfaces of the balance meter should be wiped first with a soft cloth dipped in distilled water and then with a dry cloth after which the observations may be continued.

When the polyethylene filter sweats, it is necessary to open the balance meter and wipe the polyethylene before continuing with the measurements.

(4) The error in measuring the longwave balance is due to the calibration of the balance meter with the direct solar radiation. As we know, up to the present time, nocturnal measurements of the balance are conducted by balance meters which have been checked by using direct solar radiation. However, in view of the selective absorption of radiation by the coating which covers the sensing surface of the balance meter, the sensitivity of the meter will not be the same in different spectral intervals with respect to the shortwave and long-wave radiation (ref. 1). In this connection, it became necessary to introduce corrections to the readings of the balance meter which was used to measure the longwave balance. It should be pointed out that the correction should be different for different types of balance meter coatings. Below are presented the results of a theoretical calculation of the error mentioned above incurred in measuring the longwave balance (ref. 12).

Let us assume that we have placed in a tube a meter which we use to measure

the direct solar radiation equal to $S = \int_0^{\infty} S(\lambda) d\lambda$, where $S(\lambda)$ is the magnitude

of the radiation which pertains to the spectral interval $d\lambda$.

The absorptive power of the balance meter will be designated by $\delta(\lambda)$. Then the coating on the upper sensing surface of the balance meter will absorb

the following quantity of radiation $q_1 = \int_0^{\infty} S(\lambda) \delta(\lambda) d\lambda$. The reading of the

galvanometer, which will be connected to the balance meter, is proportional to the magnitude of heat absorption, i.e., $n_1 = kq_1$, where n_1 is the reading of the galvanometer, and k is a factor.

The conversion factor of the system balance meter-galvanometer will be equal to the direct radiation magnitude determined by the control device (for example, an actinometer), divided by n_1 :

$$a_1 = \frac{S_1}{n_1} = \frac{\int_0^{\infty} S(\lambda) d\lambda}{k \int_0^{\infty} S(\lambda) \delta_1(\lambda) d\lambda}.$$

The data on the spectral absorptive power of the balance meter coatings were obtained experimentally in the work of B. P. Kozyrev and O. Ye. Vershinin (ref. 1). According to this work the absorptive power of the coatings decreases slightly with an increase in the wavelength.

Now let us assume that we are measuring the longwave balance with the balance meter.

$$B_{\text{longwave}} = \int_0^{\infty} E(\lambda) d\lambda,$$

where $E(\lambda)$ characterizes the distribution of radiation in the spectrum of effective emission.

The sensing surfaces of the balance meter will absorb the following quantity of heat:

$$q_2 = \int_0^{\infty} E(\lambda) \delta(\lambda) d\lambda.$$

The galvanometer will give a reading which is proportional to this quantity. If we use the conversion factor determined with the shortwave radiation, then the magnitude of the longwave balance B_{longwave}^* will be equal to

$$n_2 a = k \int_0^{\infty} E(\lambda) \delta(\lambda) d\lambda \frac{\int_0^{\infty} S(\lambda) d\lambda}{k \int_0^{\infty} S(\lambda) \delta(\lambda) d\lambda},$$

whereas its true value is $B_{\text{longwave}} = \int_0^{\infty} E(\lambda) d\lambda$.

Thus, the error Δ which we obtain when we calibrate the balance meter with direct solar radiation, will be equal to

$$\Delta = 1 - \frac{\int_0^{\infty} E(\lambda) \delta(\lambda) d\lambda}{\int_0^{\infty} S(\lambda) \delta(\lambda) d\lambda}.$$

The data on the spectral distribution of the effective radiation were taken from reference 10.

If we take into account the fact that for the entire shortwave region of the spectrum the value of δ may be considered constant, with a high degree of accuracy, and equal to 0.98 (ref. 1) we may write

$$\Delta = 1 - 1.02 \frac{\int_0^{\infty} E(\lambda) \delta(\lambda) d\lambda}{\int_0^{\infty} E(\lambda) d\lambda}. \quad (1)$$

The calculations carried out by means of equation (1) gave the following values for the errors obtained when we measured the longwave balance. For balance meters covered with soot dissolved in celluloid lacquer, the error in Δ constitutes 10 percent; for balance meters covered with soot dissolved in amber lacquer the error is $\Delta = 12$ percent. Thus, the absorptive power of balance meters will not be 100 percent as frequently assumed in various works, but will have a maximum of 88-90 percent.

It is necessary to note that the results of the given calculations pertain to balance meters with good new coatings. For balance meters used by the chain of stations the indicated errors may be substantially greater. Therefore, in measuring the longwave balance, the balance meters should be calibrated by means of the longwave radiation rather than with the direct solar radiation.

On the basis of the data presented above we feel that we can make the following conclusions.

(1) When measurements of the radiation balance are made at sea it is necessary to cover the balance meters with a polyethylene film, otherwise measurements become impossible due to the vertical flow of air.

(2) It is advisable to use a flat polyethylene filter because of the simplicity of its construction and because it is better preserved under natural conditions than other forms of filters.

(3) In measuring the radiation balance it is necessary to introduce an angular correction to the readings of the balance meter which must be determined for each meter. We should note that it is particularly important to introduce this correction when the altitudes of the Sun are less than 30° .

(4) It is necessary to keep the balance meter in a strictly horizontal position.

(5) When the balance meter is sprinkled with salt water or when the sensing surfaces of the balance meter are subjected to drops of rain or dew the measurement of the radiation balance should be stopped and the sensing surfaces of the balance meter which are covered with the polyethylene film

should be wiped. When the film sweats from the inside the balance meter should be dried out before measurements are continued.

(6) When the longwave balance is measured, balance meters should be used which are calibrated not for direct solar radiation but for longwave radiation. Otherwise, a corresponding correction must be applied to the readings of the balance meter.

(7) The authors also propose using balance meters with polyethylene filters for measuring the radiation balance on land, because measurements taken with unprotected balance meters when wind is present are unreliable.

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